CHAPTER 8 EXPANSION OPTIONS

8.1 Rehabilitation/Re-Powering Projects

Several major projects are proposed for the rehabilitation (re-powering) of existing facilities. These projects are included in Table 1. More details on the proposed rehabilitation and re-powering projects can be found in Chapter 3 of this Report.

Table 1 - Potential Rehabilitation and Repowering Projects

Unit	Gross Capacity after Rehabilitation, MW	Useful Life after rehabilitation, yr.	Unit Cost, $/kW (Y2000)
Thermal Power Projects			
Hrazdan Block Unit 5 Completion/Repowering	**440**	**30**	**$284.2**
Hrazdan Block Unit 4 Repowering	**280**	**20**	**$115.4**
Hydro Power Plants			
Sevan Hrazdan Cascade	**561**	**35**	**$70.9**
Vorotan Cascade	**404**	**35**	**$78.3**

8.2 New Power Technologies

In order to develop an optimal system expansion plan, the following new technologies (projects) were considered in the planning process:

- New Gas-Fired Combined Cycle Power Plants (82 MW and 400 MW size)
- Gas-Fired Gas Turbine (100 MW size)
- Coal-Fired Circulating Fluidized Bed Units (atmospheric 50 and 200 MW, pressurized 80 MW)
- Nuclear Units (Russian 640 MW and Western 600 MW)
- Hydro Plants (70 MW and 85 MW size)

It is important to note that the determination of optimal geographic location is outside of the scope of this study. Siting of the potential units will be included in the next study. This would assess the attractiveness of the projects from the following perspectives:

- access to transmission capacity
- access to fuel
- access to water resources
- access to transportation routes and communication lines
- environmental impacts

8.3 Screening Analysis Methodology

A screening analysis of several new technologies mentioned above was conducted. Also, to gain a better understanding of the proposed rehabilitation/re-powering projects, all of them were compared to the cheapest new technology alternative. As noted, this analysis serves to reduce the number of resource alternatives that need to be included in the optimization phase of the least cost generation planning process.

The screening curves take into account *capital costs* and both *fixed and variable O&M costs*, expressed in dollars per kW, at different capacity factors of each alternative technology, levelized over the life of each respective unit. The objective is to select the lowest cost units within specific bands of capacity factors as candidate resources that will proceed to the optimization phase.

8.4 Input Data

In the following two tables the data is summarized required to perform screening analysis on the proposed new and rehabilitation projects. Most of the data came from previous feasibility (pre-feasibility) studies. Some data is based on information provided by vendors. Several independent references and expert assessments were utilized as well.

Table 2 presents the summary of data used to evaluate newly proposed projects at the screening level. Table 3 presents the summary of data used to evaluate rehabilitation/re-powering projects at the screening level.

Table 2 Screening Analysis Input – New Projects

Technology / Features	Combined Cycle – Gas - Fired (1)	Combined Cycle – Gas -Fired (2)[1]	Refurbish	Gas Turbine – Gas-Fired	Nuclear Unit (1)	Nuclear Unit (2)	Circ. Fluidized Bed (1)	Circ. Fluidized Bed (2)	Circ. Fluidized Bed (3)	Hydro Power Plant (1)	Hydro Power Plant (2)
Type/Project	2x1 type	1x1 type	Hrazdan 5	---	VVER-640 (Rus)	Western	ACFB	ACFB	PCFB	Shnokh	Megri
Gross Maximum Capacity (MW)	400	82	440	100	640	600	50	200	80	70	85
Auxiliary Power Consumption %	3	3	8	1	8	8	11	11	10	1	1
Net Heat Rate (@ 100% (Btu/kWh) 75% 50% 25%	6976 7185 7813 9138	6740 6942 7549 8830	7300 7506 8320 10510	9960 10062 11253 15339	10050 10050	10400 10400	10777 10977 11595 14111	10289 10481 11070 13473	8959 9205 9664 18000	N/A	N/A
Construction (years)	2.5	2.5	1.5	2	6	5	3	3	3	5	5
Construction Pattern (%/yr)	30/60/10	30/60/10	60/40	100	30/20/20/ 10/10/10	30/20/20 / 20/10	40/40/20	40/40/20	40/40/20	30/30/20/ 10/10	30/30/20/ 10/10
Overnight Capital Cost ($/kW)	581	685	284[2]	414	1460	2000	1180[3]	900	1300	1730	1882
Overnight Capital Cost Incl. IDC ($/kW)	747.2	881.0	341.0	463.7	2166.6	(6)	1519.5	(6)	(6)	2451.0	2666.3
Decommissioning Cost ($2000)[4]					$225 million	$300 million					
O&M Cost: - Fixed ($/kW/yr) - Variable (non-fuel)[5] ($/MWh) - Other[6] ($/kW)	 14.0 0.87	 34.4 0.80	 14.8 0.92	 10.5 0.2	 27.9 83	 42.5	 12.0 1.0	 37.6 1.0	 42.4 1.0	 11.4	 13.9
Y 2000 Fuel Cost ($/MMBtu), Escalation %/yr	2.16 1%	2.16 1%	2.16 1%	2.16 1%	0.498 0%	0.481 0%	1.481 0%	1.481 0%	1.481 0%	N/A	N/A
Life of Unit, yrs	30	30	30	30	50	40	35	35	35	40	40

[1] It is proposed to consider any changes to technical parameters of 82 MW CC unit in the next Least Cost Plan report.
[2] Assumes refurbishment of existing not completed 300 MW conventional unit
[3] Assumes utilization of existing spare turbine
[4] For NPPs only. Estimate
[5] Includes limestone for CFB technologies
[6] Applies to Russia NPP first fuel load only
[6] Not calculated for units eliminated in screening analysis

Table 3 Screening Analysis Input – Proposed Rehabilitation/Re-Powering Projects

Technology / Features	**Benchmark**	**Re-Powering**	**Re-furbish**	**Hydro Rehab 1**	**Hydro Rehab 1**	**Hydro Rehab 1**	**Hydro Rehab 1**	**Hydro Rehab 1**	**Hydro Rehab 2**	**Hydro Rehab 2**	**Hydro Rehab 2**
Type/Project	Hrazdan 5	Hrazdan 4	Hrazdan 1-3	Sevan HPP	Hrazdan HPP	Gumush HPP	Kanaker HPP	Yerevan 1 HPP	Tatev HPP	Shamb HPP	Spandarian HPP
Gross Maximum Capacity MW	440	280	600	34	82	224	102	44	157	171	76
Auxiliary Power Consumption (%)	8	10	12	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Net Heat Rate (@ (Btu/kWh) 100% 75% 50% 25%	7300 7506 8320 10510	8381 8618 9553 12067	9452 9758 10564 N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Construction (years)	1.5	1.5	1	4	3	4	4	4	2	2	2
Construction Pattern (%)	30/60/10	60/40	100	40/30/20/10	40/30/30	40/30/20/10	40/30/20/10	40/30/20/10	60/40	60/40	60/40
Overnight Capital Cost ($/kW)	284[7]	115.4	3.4	100.3	31.3	46.8	215	33.9	52.5	98.3	89.7
Overnight Capital Cost Incl. IDC ($/kW)	341.0	138.6	3.8	137.9	39.9	64.3	295.6	46.6	63.0	118.0	107.7
O&M Cost: - Fixed ($/kW/yr) - Variable (non-fuel) ($/MWh)	14.8 0.92	16.4 0.92	19 1.5	4.2 0.9	3.2 0.8	3.5 0.6	4.1 0.9	3.6 0.9	3.6 0.2	3.9 0.4	3.6 0.3
Y2000 Fuel Cost ($/MMBtu), Escalation %/yr	2.16 1%	2.16 1%	2.16 1%	0	0	0	0	0	0	0	0
Life of Unit after Rehab., yrs	30	20	10	35	35	35	35	35	35	35	35

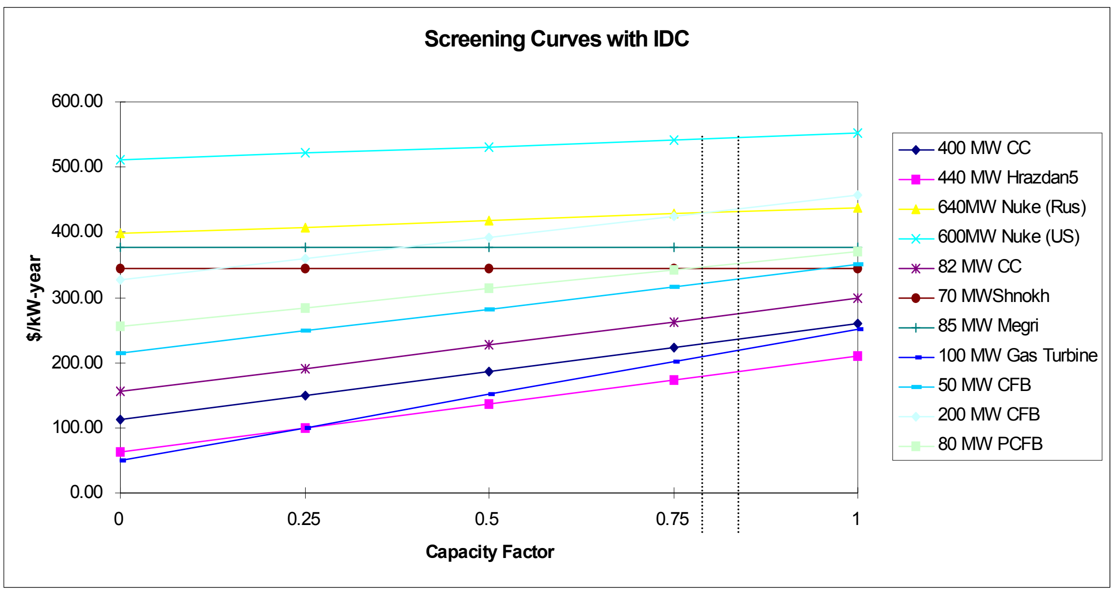
7 Assumes refurbishment of existing not completed 300 MW conventional unit

8.5 Screening Analysis Results

The screening evaluation of 11 newly proposed system expansion projects (technologies) is provided in Exhibit 1. The results are based on the data provided in Table 2, a 12 percent discount rate (DR), a 12 percent interest rate, an interest during construction (IDC) calculation based on relative construction time assumptions. All costs (capital and O&M) are levelized over the proposed unit economic life.

The Hrazdan 5 re-powering project is included in this analysis for comparison only. The placement of this project in both categories (new and rehabilitation) is because the original Unit 5 (300 MW) is not completed. This project is not treated as new, but rather as an improvement of the existing non-completed facility; hence it is included in both screening analyses.

Exhibit 1 – New Projects (Technologies)



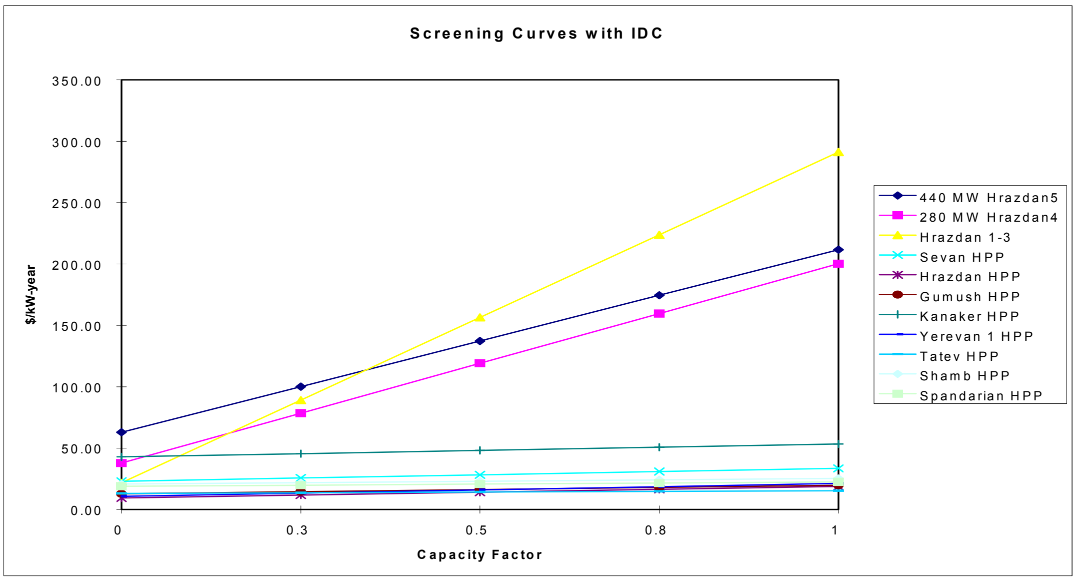
Based on this analysis, the gas-fired alternatives (i.e., Hrazdan 5 Re-Powering, New 400 and 82 MW Combined Cycles, and the 100 MW Gas Turbine) have the lowest costs on a life-cycle basis. At a 75 percent capacity factor, the levelized cost ranges from $175 to $225/kW/year for these four options.

Coal-fired technologies (atmospheric and pressurized CFBs) produce levelized costs ranging between $320/kW-year and $425/kW-year at a 75 percent capacity factor. New hydro plants produce levelized costs of between $345/kW-year and $375/kW-year. Finally, new nuclear plants have the highest levelized life-cycle cost of $430/kW-year and $540/kW-year.
It should be noted that this analysis is performed as a preliminary phase only, in order to reduce the number of economic alternatives. Based on the screening analysis three (3) new technologies were dropped and considered non-usable based on levelized cost. Optimization,

including consideration of dispatch and start-up costs, is performed later in the study. Please refer to Chapter 9 for more information.

The screening evaluation of 11 existing facilities' rehabilitation/re-powering projects is provided in Exhibit 2. The results are based on the data provided in Table 3: a 12 percent discount rate (DR), a 12 percent interest rate, and an interest during construction (IDC) calculation based on the construction time assumptions. All costs (capital and O&M) are levelized over the respective units' economic lives. The Hrazdan 5 re-powering project is included in this analysis for comparison only as the lowest cost alternative from the analysis summarized in Exhibit 1.

Exhibit 2 – Rehabilitation/Re-powering Projects



Based on the analysis performed for the rehabilitation/re-powering projects, all alternatives (except for the Hrazdan 1-3 refurbishment project) have levelized costs lower then the cheapest newly proposed expansion alternative. The proposed hydro rehabilitation projects, except for Kanaker HPP, have levelized costs ranging from $18.5/kW-year to $33.5/kW-year at a 75 percent load factor. Kanaker HPP rehabilitation has the highest levelized hydro project cost -- $54/kW-year -- which is still much lower than any other non-hydro option.

It should be noted that the Hrazdan 1-3 rehabilitation project also has low levelized costs ($37/kW-year attributable to capacity alone). This project's benefits are not fully accounted for in this screening analysis, since this unit would permit the partial or complete shut-down of existing CHP units at Hrazdan TPP. For this reason, this project was deemed acceptable and passed this preliminary screening analysis.

8.6 Summary and Conclusions of Screening Analysis

Least-Cost Alternatives

The following alternatives passed the initial screening analyses and graduated to the least-cost economic scenarios:

- All hydro rehabilitation projects (total of 8)
- All thermal rehabilitation/re-powering projects (total of 3)
- New gas-fired alternatives (total of 3)

Strategic Alternatives

Even though strategic planning for the energy sector as a whole is outside the scope of this study, several sensitivities were added to the Matrix of Scenarios (see Chapter 7 for more details) to evaluate the economics of fuel security and maximization of domestic resources use. The following options will be considered in these sensitivities:

- New 50 MW CFB unit at Hrazdan TPP
- New 70 and 85 Hydro Stations at Shnokh and Megri sites
- New 640 MW Russian VVER-640 unit at Medzamor NPP.

8.7 Recommendation on Feasibility Study Subjects

Detailed feasibility studies of several critical projects were outside of this study's scope of work. This study relies on available pre-feasibility studies and expert assessments. The following projects are therefore recommended for detailed feasibility evaluations:

- Hrazdan 5 Re-Powering to 440 MW Gas-Fired Combined Cycle
- Hrazdan 1-3 Rehabilitation and Modernization to Support Required CHP Load with Possibility of Partial or Complete Shutdown of Hrazdan CHP Plant.
- New 85 MW Hydro Power Plant at Megri

Upon completion of these studies, the proposed Least-Cost Generation Plan can be modified to accommodate new findings (if any).